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Production of Protein Enriched Ready-To-Eat Extruded Food Products Using Edible Quality Sesame Flour, Rice Flour and Bengal Gram Flour

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ABSTRACT
The oilseed processing industries generate millions of sesame flour annually, which results in a loss of edible product and presents a considerable waste disposal problem. The purpose of this research was to investigate the use of edible quality deoiled sesame flour as the protein source in the development of protein rich extruded food products. Product formulations consisting of 20-40 g 100 g^{-1} extruded food combined with rice flour and Bengal gram flour were processed in a twin-screw extruder. The resulting extrudates were analyzed for proximate and mineral composition, physical property, morphology, antioxidant, trypsin inhibitor activity, color value and sensory properties. Level of incorporation of edible sesame flour had significant effects ($p \leq 0.05$) on the protein content, physical property and color of the extrudates though the calorific values of all products are same. This research demonstrates that edible quality sesame flour can be successfully incorporated into extruded ready-to-eat food products.
Keywords: Sesame Flour, Sesame Protein, Rice Flour, Bengal Gram Flour, Extrusion, Antioxidant

INTRODUCTION

Extrusion technology is extensively used for preparation of new protein sources, such as oilseeds, leguminous seeds, leaf and single cell proteins [1]. Providing safe, nutritious, and wholesome food for poor and undernourished populations had been a major challenge for the developing world [2], [3]. Edible oilseeds are known to be a good source of proteins with desirable amino acids. Among the oil seeds sesame (*Sesamum indicum*) seed meal is regarded for having rich source of sulphur containing amino acids and thus has a great potential to enhance the nutritive value of Indian diets through proper fortification [4],[5],[6]. Sesame seeds have been consumed throughout the world for centuries. Traditionally used oil extraction machinery in India results into poor oil extraction and oilseed cake contains substantial amount of residual oil [7]. This oilseed cake which is generally used in animal feeds could be exploited for use in food Products of the proper processing. Sesame seed meals with high protein concentrate (41.15%) can be used to make food by mixing with other ingredients such as edible rice flour or corn flour with high PER (protein efficiency Ratio) for consumption by protein deficient population. Such Products are expected to enhance the nutritional value of Indian diets as well as enable to consumer to get high quality protein at low cost. Mixing of Sesame meal with other materials particularly with cereal flours can be best achieved by extrusion processing. In fact, extrusion technology is used for preparation of seed protein concentrates combined with appropriate flours. The extruded products from sesame flour rich food produces are likely to take care of the protein nourishment of the children and adults of low income group of population thereby achieve enormous dietary health benefits.

The present study therefore aimed to investigate the adaptability of the twin screw extruder in the production of protein and cereal based co- extruded products from sesame flour as the desired protein source and flour like rice and bengal gram to incorporate food ingredients such as carbohydrates and micronutrients etc. followed by evaluation of the functional composition and properties.

MATERIALS AND METHODS

Duhulled sesame seeds, regular rice flours, bengal gram flour, sugar, tata iodized salt all were purchased from B.M.Agarwal, Bhowanipur, Jagubabu’s Bazar, Kolkata, W.B. Sesame seed were deoiled by using Soxhelt extraction procedure. Edible deoiled sesame flour having composition of protein 41.15%, moisture 2.19%, fat 1.49%, carbohydrate 49.02%, ash 6.15% and fiber 3.46%.All chemicals used were MERCK grade. Multi-vitamin and mineral capsule named A to Z was brought from local medical shop.

Feed Blend Preparation

Four isocaloric (3.4 kcal g^{-1}) ingredient blends with a similar salt , sugar , Bengal gram flour, water and vitamin content of 1.4%, 21%, 14%, 3.2% and 0.4% respectively, each with increasing contents of deoiled sesame flour (20%, 30%, 40% and 50%) and decreasing amounts of rice flour (40%, 30%, 20% and 10%) (**Table 1**), were used to prepare nutritionally enriched ready-to-eat protein rich extruded food products. Approximately 1 kg of each blend was extruded. After the composition of the mix to be used has been decided upon, the next step was to calculate the amount of each ingredient which was to be used. This first part of work was done with great care for two very important reasons. First, a satisfactory quality in the finished product was possible only when the proper proportion of constituents was used in the mix. Second important reason for giving so much attention to the calculation and preparation of the mix pertained to the sensory acceptance. All the ingredients were weighed and then mixed in a mixer for 20 min in order to achieve uniformity before extrusion. Samples were stored at room temperature for 24 h before extruding.

Table 1. Ingredient components (g/100 g) in the feed blends and their compositions (dry basis) used in the study

Ingredients	Product-I	Product- II	Product-III	Product- IV
		Dry Weight of Ingredients (g/100 g)		
Deoiled Sesame Flour	20	30	40	50
Rice Flour	40	30	20	10
Bengal Gram Flour	14	14	14	14
Sugar	21	21	21	21
Salt	1.4	1.4	1.4	1.4
Vitamin	0.4	0.4	0.4	0.4
Water	3.2	3.2	3.2	3.2
Total	100.00	100.00	100.00	100.00
		Feed Composition (g/100 g)		
Protein	14.04	17.46	20.90	24.33
Fat	1.21	1.34	1.47	1.54
Moisture	9.738	8.757	7.776	6.795
Ash	1.744	2.399	2.934	3.529
Fiber	1.11	1.40	1.688	1.973
Carbohydrate	73.26	70.04	66.93	63.64
Energy (Kcal)	342.58	344.55	347.89	349.47

Table 2. Proximate components of extruded food products

Ingredients (g/100 g)	Product -I	Product- II	Product- III	Product- IV
Protein	15.12±0.32[d]	18.59±0.32[c]	22.11±0.36[b]	24.59±0.34[a]
Fat	1.32±0.12[d]	1.4±0.14[c]	1.55±0.12[b]	1.59±0.13[a]
Moisture	2.59±0.24[s]	2.22±0.25[c]	2.28±0.28[b]	1.84±0.29[d]
Ash	1.83±0.26[d]	2.36±0.27[c]	3.1±0.18[b]	3.71±0.29[a]
Fiber	1.29±0.22[d]	1.49±0.24[c]	1.6±0.25[b]	2.07±0.28[a]
Carbohydrate	77.85±0.71[a]	73.94±0.78[b]	69.36±1.15[c]	66.2±0.76[d]
Energy (Kcal)	340.94±0.58[c]	342.05±0.64[a]	341.68±0. 52[b]	341.0±0.55[b]

Results are expressed as mean ± SD (n=3). Mean Values having different superscript letter in rows are significantly different ($p<0.05$).**Product–I**: 20 % DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: Rice Flour.

Table 3. Mineral composition of extruded food products

Mineral (mg/100g)	Product -I	Product- II	Product- III	Product- IV
Na	540.62±1.25[b]	540.81±1.29[b]	540.99±2.55[b]	541.18±2.54[a]
Ca	233.34±2.65[d]	271.13±2.67[c]	308.95±2.48[b]	346.77±2.37[a]
Mg	145.12±1.58[d]	146.41±1.59[c]	147.68±1.39[b]	148.95±1.48[a]
Mn	3.55±0.59[a]	3.28±0.67[b]	3.19±0.67[c]	3.10±0.98[d]
K	169.32±2.48[a]	163.52±2.11[b]	157.72±2.98[c]	151.92±1.59[d]
Zn	13.07±0.98[a]	13.04±0.97[a]	13.01±0.84[a]	12.97±0.89[b]
Fe	1.29±0.18[a]	0.88±0.19[b]	0.88±0.32[b]	0.88±0.21[b]
Cu	47.38±3.25[ab]	47.57±3.49[a]	47.77±2.45[a]	47.96±2.65[a]
Pb	0.00	0.00	0.00	0.00
Cd	0.00	0.00	0.00	0.00
Cr	0.00	0.00	0.00	0.00

Results are expressed as mean ± SD (n=3). Mean Values having different superscript letter in rows are significantly different ($p<0.05$).**Product–I**: 20 % DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: Rice Flour

Table 4. Physical properties of extruded food products

Properties	Product –I	Product- II	Product- III	Product- IV
Mass Flow Rate (g/sec)	2.15±0.21[d]	3.12±0.55[c]	4.34±0.54[b]	4.89±0.59[a]
Tap Density(g/cc)	0.52±0.02[d]	0.54±0.03[c]	0.55±0.02[b]	0.56±0.05[a]
True Density(g/cc)	1.48±0.03[a]	1.35±0.05[b]	1.24±0.04[c]	1.12±0.04
Bulk Density(Kg/cm^3)	0.28±0.02[d]	0.30±0.02[c]	0.35±0.02[b]	0.38±0.05[a]
Moisture Retention (%)	26.39±1.15[d]	25.45±1.12[c]	29.34±1.12[a]	27.12±1.16[b]
Expansion Ratio	1.19±0.27[a]	1.12±0.26[b]	1.08±0.24	1.02±0.21
Water Solubility Index (%)	0.22±0.13[d]	0.25±0.11[c]	0.30±0.16[b]	0.34±0.15[a]
Water Holding Capacity (%)	184.52±2.45[a]	155.25±2.26[c]	152.24±2.45[d]	184.25±2.26[b]
Water Absorption Index (%)	2.23±1.11[a]	1.19±1.46[b]	1.15±1.27[c]	1.05±1.14[d]
Oil Absorption Capacity (%)	2.75±0.05[a]	1.24±0.06[d]	1.29±0.04[c]	2.71±0.06[b]

Results are expressed as mean ± SD (n=3). Mean Values having different superscript letter in rows are significantly different ($p<0.05$).**Product–I**: 20 % DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: Rice Flour

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Table 5. Color properties of extruded food products

Properties	Product -I	Product- II	Product- III	Product- IV
L*	90.00±0.12^{a}	88.60±0.34^{b}	88.1±0.45^{c}	90.0±0.26^{a}
a*	0.9 ±0.02^{b}	1.0±0.01^{a}	0.8±0.03^{c}	0.8±0.05^{c}
b*	11.5±0.22^{b}	12.1±0.41^{a}	11.3±0.38^{c}	10.5±0.35^{d}
c	11.5±0.15^{b}	12.2±0.25^{a}	11.4±0.11^{c}	10.6±0.15^{d}
h	85.6±0.24^{b}	85.1±0.26^{c}	85.9±0.18^{a}	85.6±0.16^{b}

Results are expressed as mean ± SD (n=3). Mean Values having different superscript letter in rows are significantly different ($p<0.05$).**Product–I**: 20 % DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: RiceFlour

Table 6. Antioxidant activity of extruded food products

	Product -I	Product- II	Product- III	Product- IV
Antioxidant Activity (Before Extrusion)				
Total Phenolics (μgE of gallic acid g^{-1})	1716 ±3.65^{d}	2012±2.45^{c}	2422±2.87^{b}	2885±5.26^{a}
DPPH radical scavenging activity (%)	20.45±0.95^{d}	30.49±0.75^{c}	34.66±0.85^{b}	41.06±0.59^{a}
Antioxidant Activity (After Extrusion)				
Total Phenolics(μgE of gallic acid g^{-1})	2054±5.21^{d}	2524±4.78^{c}	3047±1.99^{b}	3514±4.26^{a}
DPPH radical scavenging activity (%)	23.58±0.98^{d}	36.45±0.48^{c}	42.18±0.55^{b}	49.25±0.75^{a}

Results are expressed as mean ± SD (n=3). Mean Values having different superscript letter in rows are significantly different ($p<0.05$).**Product–I**: 20 % DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: RiceFlour

Table 7. Sensory evaluation of extruded food products on 0 day and after 3 months during storage condition at 37^{0} C, on the basis of 9 point hedonic rating

Sensory Properties	Product -I		Product- II		Product- III		Product- IV	
	0 day	**3 months**	**0 day**	**3 months**	**0 day**	**3 months**	**0 day**	**3 months**
Colour	6.26±0.25^{b}	6.45±0.29^{b}	8.08±0.28^{c}	8.24±0.69^{c}	8.55±0.48^{d}	8.69±0.11^{d}	6.41±0.64^{a}	6.84±0.32^{a}
Texture	6.94±0.29^{b}	6.95±0.27^{b}	8.15±0.69^{c}	8.19±0.65^{c}	8.25±0.29^{d}	8.25±0.48^{d}	6.94±0.24^{a}	6.93±0.25^{a}
Aroma	7.00±0.45^{a}	7.15±0.16^{a}	7.35±0.45^{d}	7.49±0.28^{d}	7.21±0.49^{b}	7.20±0.54^{c}	7.26±0.47^{c}	7.16±0.19^{b}
Overall acceptability	6.77±0.54^{a}	6.75±0.65^{b}	8.22±0.29^{c}	8.14±0.34^{c}	8.30±0.67^{d}	8.28±0.66^{d}	7.17±0.11^{b}	6.25±0.37^{a}

Results are expressed as mean ± SD (n=3). Mean Values having different superscript letter in rows are significantly different ($p<0.05$).**Product–I**: 20 % DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: Rice Flour.

Figure 1. Resulting Extrudates.

Product–I: 20% DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: Rice Flour.

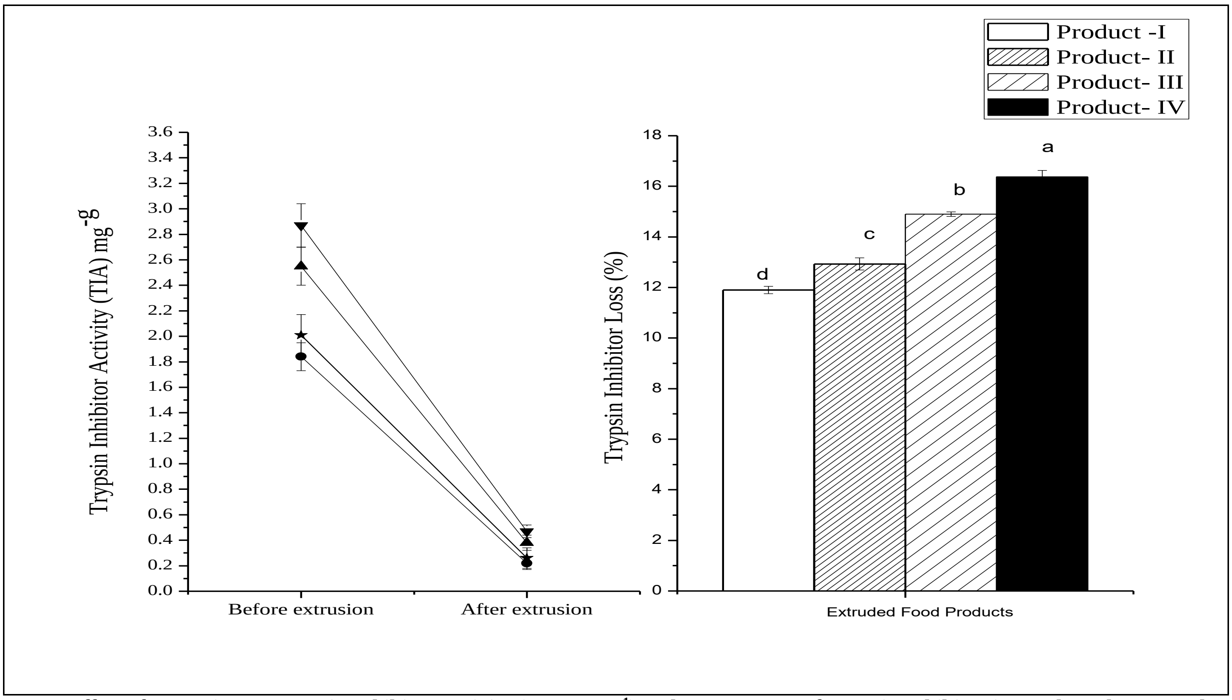

Figure.2 . Effect of Extrusion on Trypsin Inhibitor Activity (TIA, mg g^{-1}) and Percent Loss of Trypsin Inhibitor in Food Products. **Product –I**: 20 % DSF+40%RF; **Product-II**: 30 % DSF+30% RF; **Product-III**: 40 % DSF+20%RF; **Product-IV**: 50 % DSF+10%RF; DSF: Deoiled Sesame Flour; RF: Rice Flour.

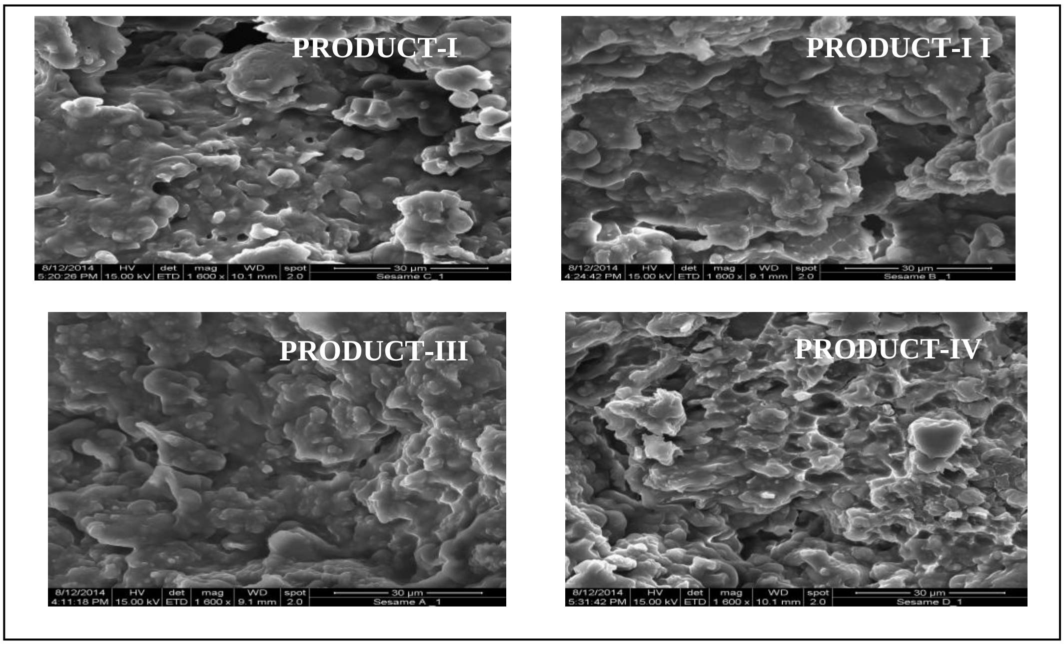

Figure.3. Scanning Electron Microscope Image of Different Extruded Food Products. **Product –I**: 20 % DSF+40%RF (15 kV, 1600×M); **Product-II**: 30 % DSF+30% RF (15 kV, 1600×M); **Product-III**: 40 % DSF+20%RF (15 kV, 1600×M); **Product-IV**: 50 % DSF+10%RF (15 kV, 1600×M); DSF: Deoiled Sesame Flour; RF: Rice Flour

Extrusion Process
The blend was extruded using a co-rotating twin screw extruder; with a smooth barrel. The extruder has three independent zones and the effective cooking zone temperatures were set to 100, 110 and 120°c, respectively for zones 1, 2 and 3 in the barrel. The length to diameter (l/d) ratio for extruder was ~20:1. The diameter of the hole in the die was 6mm with a die length of 27 mm. temperature profile in the feed and compression metering zone were kept out constant at 55 and 75°c, respectively. The mixing was done by hand protected by plastic glove at the laboratory requirement. A face cutter was used to cut extrudates as they left the extrusion die. The extrudates were collected and dried in oven air at 120°c for 5 min. the product was cooled and tempered at 4°c and also stored into food grade polyethylene bag for further analysis.

Proximate Composition
Percent moisture, crude fat, ash, crude fiber and crude protein contents were determined using the methods of Association of Official Analytical Chemists [9]. The carbohydrate was calculated by difference. Samples were analyzed in triplicates. Energy values were obtained using the Atwater formula where by fat, protein, and carbohydrate supplied 9, 4, 3.75 Kcal g^{-1} respectively.

Mineral Composition
Mineral contents were evaluated in extruded samples according to AOAC [9].

Physical Property
Mass flow rate (MFR) was measured by collecting the extrudates in polyethylene bags for a specific period of time, as soon as it comes out of the die its weight taken instantly after its cooling to ambient temperature [10].Tap density, true density, expansion ratio and bulk density were determined by the procedure of Deshpande and Poshadri [11].The moisture content of the feed and extruded samples was determined by AOAC method 925.10 [12] .Water absorption index (WAI) and water solubility index (WSI) were determined by the method of Anderson [13]. Oil absorption capacity was determined by the method of Deshpande and Poshadri [11].

Colour
Colour (L*, a*, b* values) of the samples was determined by using Konica Minolta Color Colorimeter (Cr-10). L* is known as the lightness and extends from 0 (black) to 100 (white). The other two coordinates a* and b* represent redness (+ a) to greenness (- a) and yellowness (+ b) to blueness (-b), respectively were recorded. Three measurements were taken for each sample and their means were reported.

Total Phenolics
A modified method of Skerget *et al*. [14] was used to calculate the concentration of total phenolics in the samples as microgram equivalents of gallic acid per gram of dry sample using UV – vis Spectrophotometer (Agilent V-630). The oxidizing agent used was the Folin–Ciocalteu reagent. The samples were extracted with pure methanol at 40^0 C.

Free Radical Scavenging Activity
The free radical scavenging activity (antioxidant capacity) of the extruded samples was measured by 1, 1diphenyl-2-picrylhydrazyl (DPPH) method [15].

Trypsin Inhibitor Activity (TIA)
Trypsin inhibitor activities were determined using the procedure of kakade *et al.* [16].

Microstructure of the Extruded Food Products
To study the microstructure of the sesame based extruded products, (scanning electron microscope broken by a kitchen knife with a length of 5–10 mm was sputter coated with gold. The sample was then transferred to the microscope where it was observed at 15 kV.

Sensory Evaluation
The Extruded samples were kept at 37 °C for 24 h (0 day) and also during storage for 3 months at 37 °C for evaluation. 50 members were chosen from the Department of School of Community Science and Technology, IIEST, Shibpur, Howrah, West Bengal**.** They were assisted in developing a consensus evaluation for flavor attributes for extruded Food Products. Evaluation was done at Nine Point Hedonic Scale. The quality properties that were evaluated were color, texture, flavor and overall acceptance. The quality information contained on the sensory performance was indicated as 9=like extremely, 8=like very much, 7=like moderately, 6=like slightly, 5= neither like or dislike, 4=dislike slightly, 3= dislike, 2=dislike very much, 1=dislike extremely [17].

Statistical analyses
The experiments were performed in a completely randomized design. All experiments were conducted in triplicates and the mean values and standard deviations were calculated. Analysis of variance was performed and the results were separated using Tukey test ($p\leq0.05$).

RESULT AND DISCUSSION
Incorporation of sesame flour influenced both the processing behavior as well as the resulting extrudate characteristics externally. **Figure 1** shows that the extrudates changed in texture and appear to be more homogeneous with increasing sesame flour percentage levels.

Proximate Composition
The proximate composition the extruded food products is given in **Table 2** .Protein content was minimum for extruded Product-I (15.12±0.32) followed by Product-II (18.59±0.32), Product-III (22.11±0.36) and Product-

IV (24.59±0.34). The variations in the protein content of extrudate samples were very high, due to initially designed to have increased percentage of protein levels as by addition of Sesame flour in the feed mixtures. The moisture content of the samples ranged from 1.84 to 2.59 g. The moisture content was higher in Product-I (2.59±0.24) and lower in Product-IV (1.84±0.29). Among the products carbohydrate content of Product-I (77.85±0.71) was higher and lower in Product-IV (66.2±0.76). The energy values of the all Products are having almost same calorific value (3.4Kcal $g^{-1)}$.The crude fiber of the extrudates ranged from 1.29 to 2.06 g. The Products made from 50% edible sesame flour were observed to have high ash and higher crude fiber content.

Mineral Composition

The mineral content of extruded food products are tabulated in **Table 3**. All extruded food products is good source of important minerals and they might be explored as a viable supplement and ready source of dietary minerals. With higher proportion of defatted sesame flour included in the extruded Product-IV, higher Na, Ca, Mg, Mn, K, Zn, Fe and Cu was observed and formulations with lower proportion showed a lower Na, Ca, Mg, Mn, K, Zn, Fe and Cu for Product- III followed by Product-II and Product-I. Therefore, as the proportion of defatted sesame flour in the formulation increased, the extrudate mineral content value was progressively increased. Lead, cadmium, and chromium that were below the limit of detection could be an indication that the investigated seeds are free of toxic metals.

Physical Properties

Mass flow rate (MFR) was minimum for extruded Product-I (2.15±0.21) followed by Product-II (3.12±0.02), Product-III (4.34± 0.08) and Product-IV (4.89±0.59). The variations in the mass flow rate of extrudate samples were very high, due to differences in moisture content in the feed mixtures. The tap density decreased with optimum level proteins in the extruded product. The tap density was less for Product-I (0.52±0.02) than Product–II (0.54±0.03), Product-III (0.55±0.02) and Product-IV (0.56±0.05). The true density was minimum in case of Product-IV (1.48±0.03) followed by Product-III (1.24±0.04), Product-II (1.35±0.05) and Product-I (1.48±0.03).The true density increased with carbohydrate in extrudates. Similar findings were observed by Deshpande et al. [11] and Qing et al. [18].The bulk density of was minimum in case of Product-I (0.28±0.02) followed by Product-II (0.30±0.02), Product-III (0.35±0.02) and Product-IV (0.38±0.05).Bulk Density may be due to the presence of more crude fiber in the extrudate product. Similar types of results were observed by Singh *et al*. [10] and Vijaykumar and Mohankumar [19]. Expansion ratio was significantly lower in Product- IV (1.02±0.21) than that of Product-III (1.08±0.24), Product-II (1.12±0.26) and Product-I (1.19±0.27). Increase in expansion ratio with increase in level of rice flour and feed moisture as well as addition of defatted Sesame flour may be attributed to increase in protein content [20].The Water Solubility Index was more for Product- IV (0.34±0.15) followed by Product-III (0.30±0.16) and Product-II (0.25±0.11) and Water Solubility Index was less for Product-I (0.22±0.13). The Water Solubility Index of the extrudates increased when defatted sesame flour incorporation increased from 10 to 50% in the product. The water absorption index of the extrudates increased with increase of rice flour in the product. The water absorption index was found to be more for extruded Product-I (2.23±1.11) followed by extruded Product-II (1.19±0.27), Product-III (1.15±1.27) and Product-I (1.05±1.14). These results are in conformity with the observations made by Chávez-Jáuregui *et al.* [21].The water holding capacity was maximum for extruded Product-I (184.52±2.45) due to higher level of carbohydrate and Product-IV (184.25±2.26) due to higher level of crude fiber and minimum for Product-III (152.24±2.45) and Product-II (155.25±2.26). Oil absorption was found to be more for extruded Product-I (2.75±0.05) and for Product-IV (2.71±0.06)than Product-III (1.29±0.04) and Product-II(1.24±0.06), higher absorption of oil may be attributed to presence of less fat and more crude fiber in case of extrudate Product-I and Product-IV respectively. The highest moisture retention was found in the extruded product prepared using composite flour Product-III which may be due to the increase in protein content which was the result of maximum utilization of protein (20%) in the Product-III.

Color

The colour value of extruded food products are tabulated in **Table 5**.With higher proportion of rice flour and defatted sesame flour included in the extruded product, higher L* value (90.00±0.12) was observed and formulations with lower proportion of showed a lower L* value for Product-II and Product-III (88.60±0.34 and 88.1±0.45 respectively). Therefore, as the proportion of defatted sesame flour in the formulation increased, the extrudate brightness (L* value) was progressively increased. The table shows that large b* values were observed for Product-II (1.0±0.01) with 30% both rice flour and defatted sesame flour. The increase in the defatted sesame flour addition to Product-II maximum increased a* values which correspond to redness. If we are interested in a light colored as well as protein rich Product, it will be wise to choose higher proportion of Protein and lower proportion of crude fiber incorporated extrudate such as Product- III.

Total Phenolics

Table 6 show changes in the total phenolics, as well as in the overall antioxidant properties of different sesame based extruded food Products in relation to twin screw extrusion, In the present study, total phenolics content was found to increase However,

literature data on the effect of extrusion cooking on sesame phenolic compounds are very limited.

Free Radical Scavenging Activity

Extrusion cooking led to a significant increase in DPPH radical scavenging activity and these increases in Product – I, Product – II, Product- III and Product- IV were 3.13%, 5.96%, 7.52% and 8.22%, respectively. It was found that the Product- IV after extrusion had the significantly strongest ($p \leq 0.05$) scavenging activity (49.25%) against DPPH It is widely known that the Maillard reaction Products influence the antioxidant activity of plants [22]. The increase in antioxidant activity could be explained by the formation of Maillard browning components, which enhanced the antioxidant activity of extruded products. Another reason for the increase in antioxidant activity could be due to the increase in total phenolic [23]. In **Table 6**, the antioxidant activity of sesame based product after extrusion was stronger than that of before extrusion treatment.

Trypsin Inhibitor Activity (TIA)

The trypsin inhibitor activity of extruded food products are shown in **Figure.2**. Extruded Product-I, Product-II, product-III and Product- IV had low levels of TIA (0.22 ± 0.05, 0.26±0.08, 0.38±0.06 and 0.47±0.05 mg/g, respectively).Extrusion in all the food products caused a significant reduction ($p \leq 0.05$) in TIA (reductions were 11.9%,12.93%,14.9% and 16.37 %, respectively). Although, extrusion was performed in a lower temperature (120℃) it considerably decreased TIA and this could be attributed to the faster and more efficient heat transfer by extrusion treatment.

Microstructure of the Extruded Food Products

Figure 3 shows cross sectional morphologies of the extruded sesame based food Products. The internal structures of the extruded products were affected by the ratio of sesame flour, rice flour and Bengal gram flour mixture. It had been observed that the increment of protein in extruded food products had resulted in compact structure with devoid of air cell. Higher amount of protein in the extruder product resulted in formation of unbroken fiber while, less compacted structure was revealed with less protein.

Sensory Evaluation of Extruded Food Products

According to **Table 7** the Extruded color was affected by the increased incorporation of edible sesame flour. Extruded Product-III prepared using 40% edible sesame flour and 20% rice flour had the highest color scores (8.55±0.48 on 0 day and 8.69±0.11after 3 months).The received color score values were declined with uprising the incorporation level of rice flour till reached its lowest value at the level of 40% as in Product- I (6.26±0.25 on 0 day and 6.45±0.29 after 3 months). The texture of prepared extruded product was not affected by adding the edible sesame flour except the prepared product using 50% edible sesame flour, it received the least value., yet it was significantly equal to those of extruded Product -I (6.94±0.29 on 0 day) supplemented with 40% rice flour. No variation was noted in aroma between all extruded Products, which prepared using edible sesame flour at levels 20%, 30% 40% and 50% sample. The overall acceptability reflected all the previously judged quality attributes and therefore the obtained overall acceptability established the possibility to use the increment level until 40% of edible sesame flour to prepare the extruded products with non-significant difference compared to other sample. Sensory evaluation studies indicate that edible sesame flour with rice flour and Bengal gram flour can be used satisfactorily as a food ingredient in a wide range of foods.

The products are characterized by unique properties including morphological and sensory characteristics. it can be summed up from the observations of the proximate composition, various physical properties and antioxidant activities of the extruded food products prepared from edible quality sesame flour along with desired materials to provide the required nutritional properties that protein enriched ready to eat products at low cost appear is quite promising for the low income group of population. The success of such products will improve the agricultural, industrial and societal economy.

CONCLUSION

Edible sesame flour as source of protein can be utilized with rice flour and Bengal gram flour by co extrusion in producing nutritionally high quality food products at low cost.

CONFLICT OF INTEREST

The authors are unanimous in publishing this paper. There is also no body to contradict this manuscript.

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